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Annotated Bibliography on Solid State Optical and Infrared Maser Materials

(A Summary of Abstracts from Current Literature up to December 1961)

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FOREWORD

While preparing for contractual research in the field of optical maser materials, the author conducted an extensive literature search. We believe that the results of this survey can be of value to other groups interested in optical masers. Only articles in journals from the beginning of optical maser research to the end of 1961 were considered. Technical reports and notes by government agencies and survey articles in non-scientific or pseudo-scientific magazines were omitted.

The work was done under Project No. 7371, "Applied Research in Electrical, Electronic, and Magnetic Materials," Task No. 737101, "Applied Research on Dielectric Materials."

ABSTRACT

This report contains abstracts of approximately 110 articles from 25 different scientific journals. It covers theory and survey; solid state maser materials; maser optics; properties (coherence and others); related basic research; and organic, semi-conducting, and gas masers. The survey includes articles from the beginning of the optical maser research to December 1961.

This technical documentary report has been reviewed and is approved.

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INTRODUCTION

The field of quantum-electronics is at present one of the most active areas of physics and electronics. Hundreds of scientists all over the world are working in the maser (Microwave Amplification by Stimulated Emission of Radiation) field. The laser is an extension of maser techniques into the optical region of the electromagnetic spectrum.

The first masers were developed in 1955, but it was not until 1960 that it was possible to generate a beam of coherent light in a solid state device through stimulated emission.

This new device opens the way to many new applications in the areas of communications and guidance systems, cutting and welding of refractory metals, optics, medicine, and many other areas.

The development of suitable materials is now rapidly progressing in many laboratories. The construction of continuously operating optical masers, which has just been announced, is an outstanding accomplishment of materials research. This form of research may be expected to continue at the present or even at an increased rate in the years to come. Hence, this review will eventually become obsolete.

Manuscript released by the author 29 November 1962 for publication as an ASD Technical Documentary Report.

BIBLIOGRAPHY

I. Optical-Infrared Maser Theory-Survey Articles

Number 8

Optical Pumping
Arnold L. Bloom
Scientific American (October 1960)

Historical and qualitative description of optical pumping including its application to the rubidium magnetometer is presented. Absorption and transmission effects resulting from the various energy levels is given also. The article is valuable for an initial survey into the field.

Number 11

Optical Methods of Atomic Orientation and Magnetic Resonance
A. Kastler (Laboratoire de Physique, École Normale Supérieure, Paris, France)
Journal of the Optical Society of America, Vol. 47, No. 6, (460-465) (June 1957)

Atomic orientation has been obtained with the sodium atom. The orientation effects have been studied by detection of radio-frequency resonance signals in the ground state. Orientation can be increased by adding a foreign gas to the pure sodium vapor.

Number 27

AID Report 61-89 (AD No. 257929)
Subject: Solid State Laser Research (6 June 1961)

Interpretation of a report "Generation of Coherent Light by Means of Solids" (Basov, Krokhin, and Popov in Akademiya Nauk SSSR. Vestnik, No. 3, March 1961). The authors present a brief review of the then current problems of the optical maser. A review of the article as it may apply to the Russian SOA is also provided.

Number 29

Optical Masers
H. R. Lewis
International Science and Technology, (January 1962)

This is a basic survey of optical pumping its application to stimulated emission, and the characteristics of the output of the optical maser. Included also is a descriptive outline of its uses. It is useful as basic background material.

Number 35I

Stimulated Optical Emission in Fluorescent Solids, I. Theoretical Consideration
T. Maiman (Hughes Aircraft Company)
The Physical Review, Vol. 123, No. 4, 1145-1150 (August 15, 1961)

A theoretical analysis of stimulated emission processes in fluorescent solids is presented. The kinetic equations are discussed. Comparison of the excitation intensity for a 3 and a 4 level system is given. The spectral width of stimulated emission is discussed with imperfect crystals considered.

Number 35II

Stimulated Optical Emission in Fluorescent Solids, II Spectroscopy and Stimulated Emission in Ruby
T. H. Maiman; R. H. Hoskins, I. J. D'Haenens, C. K. Asawa, and V. Evtuhov (Hughes Research Laboratories)
The Physical Review, Vol. 123, No. 4, 1151-1157 (August 15, 1961)

Stimulated emission from ruby under pulsed excitation has been studied in some detail; the observations are found to depend strongly on the perfections of the crystal under study. Experimental results are provided.

Number 48

Theory of Laser Oscillations in Fabry-Perot Resonators
J. Kotik and M. C. Newstein (Technical Research Group)
Journal of Applied Physics 32, No. 2 (February 1961)

The oscillation condition for a Fabry-Perot resonator is derived from an integral equation for the angular spectrum of the field. The integral equation involves the scattering matrices of the end mirrors. This integral equation leads to a stationary expression. An approximate necessary and sufficient condition for oscillation normal to the reflectors is derived.

Number 61

Generation of Optical Harmonics
P. A. Franken, A. E. Hill, C. W. Peters, and G. Weinreich
(Harrison M. Randall Laboratory of Physics, University of Michigan)
Physical Review Letters, 7, No. 4 (August 15, 1961)

Using a crystalline quartz sample, a second harmonic (3472Å) of ruby optical maser illumination was observed. The generation of the harmonic is the result of using non-linear material and not a two photon process.

Number 76

Possible Methods of Obtaining Active Molecules for a Molecular Oscillator
N. G. Basov, A. M. Prokhorov, P. N. Lebedev (Institute of Physics)
Journal of Experimental and Theoretical Physics, 28, 249-250 (1955)
(in Russian)

The authors give a summary of methods for constructing a low frequency molecular oscillator. They refer to two old methods described in 1954 by them and Townes et al. in the USA. The description is very clear.

Number 80

Optical Maser Design
J. H. Sanders (Bell Telephone Laboratories on leave from Clarendom Laboratories, Oxford, England)
Physical Review Letters, 3, 10 p. 86 (1959)

The author briefly discusses the ineffectiveness of photon excitation and proposes electron impact excitation.

Number 97

Spektrum and Struktur kristalliner Europiumsalze
K. H. Hellwege and H. G. Kahle (II Physikalisches, Institut, Univerisitaet, Goettingen)
Zeitzchrift fur Physik, 129, 0,62-84 (1951)

This article gives a detailed and basic picture of parts of the crystalline field theory. An especially valuable discussion of anisotropy of thermal contraction in crystals is presented.

Number 112

General Analysis of Optical, Infrared, and Microwave Maser Oscillator Emission
J. R. Singer and S. Wang (Miller Institute and Electrical Engineering Department, University of California)
Physical Review Letters, 6, No. 7 (April 1, 1961)

The equations governing coherent emission from quantum mechanical amplifiers using either electric or magnetic dipole transitions are generalized. It is found that amplitude modulation of the output is to be expected in all maser oscillators except those in which excited atoms are supplied much faster than the depopulation rate which is due to coherent induced emission.

Number 118

La Production et L'Amplification
D'oscillations Radio électrique à l'aide de
Transitions Moléculaires ou Atomiques
G. Goudet (Laboratoire Centrale de Telécommunications, Paris)
L'Onde Eléctrique, No. 379, (October 1958)

A basic explanation of quantum mechanics and the application to masers (microwave and optical), and the application of these devices to various fields of science is given (in French).

Number 133

Optical Orientation of Atoms and its Applications
G. V. Skrotskii and T. G. Izyumova
Soviet Physics USPEKHI, Vol. 4, No. 2 (September 1961) 27 pages)

A complete presentation of stimulated emission causes and effects is given. Included are sections on: optical orientation, optical detection of orientation, effect of relaxation phenomena on optical pumping, detection of radio frequency resonance, practical applications, orientation produced by exchange coupling, and optical pumping in solids (81 refs).

Number 136

Optical Masers
Arthur L. Schawlow
Scientific American (June 1961)

A general history and basic introduction to stimulated emission is provided. Applications and expected further developments of optical masers are also provided.

Number 137

State of the Art: Optical-IR-Masers
Space/Aeronautics Journal
R and D Technical Handbook
1961-62 E lo.
Ewald, D.E.

This is a short survey with data table of available masers.

Number 140

Infared and Optical Masers
A. L. Schawlow (Bell Telephone Laboratories)
The Solid State Journal, 2, No. 6 (June 1961)

A basic description of the optical maser is provided. Various mathematical expressions pertaining to intensity distribution within the ruby crystal as a function of such parameters as: spontaneous emission lifetime, band-width, statistical weights, and population of the energy levels are presented. A comparison is made between the Fabry-Perot Interferometer and the reflecting surface of the ruby crystal. Mode of oscillation and parameters affecting the number of modes/frequency interval are also reported.

Number 151

Optical Mixing
M. Bass, P. A. Franken, A. E. Hill, C. W. Peters, G. Weinreich (University of Michigan)
Physical Review Letters, 8, No. 1, p. 18 (January 1, 1962)

The observation of the sum frequency in the near ultraviolet of two ruby laser beams of different frequencies coincident simultaneously upon a piezo-electric crystal is reported. In the experiment, one of the Trion Instruments Inc., pulsed ruby lasers was operated at room temperature and the other at liquid nitrogen temperature.

Number 152

Mixing of Light Beams in Crystals
J. A. Giordmaine (Bell Telephone Laboratories)
Physical Review Letters, 8, No. 1, p. 19 (January 1, 1962)

The mixing of plane light waves having different directions of propagation and the attainment of coherence volumes of about 0.2 cm^3 in the production of second harmonic radiation is reported. Special techniques were used for the second harmonic generation in the negative uniaxial crystal.

Number 164

Generator of Short Light Pulses
G. S. Vil'Dgrube, YU. A. Kolosov, and Zh. M. Ronkin
Bulletin of the Academy of Sciences of the USSR, Physical Series, 25, 9, 1180, (September 1961) (Izevestiya Akademii Nauk S. S. S. R. SeriYa Fizicheskaya)

Number 175

Die Bestimmung Der Spin-Polarisation Aus Transparenz-Änderungen Beim Optischen Pumpen Mit Der Natrium - D_1 - Linie
Mit-4 Figuren In Text
H. Boersch, W. Raith and M. Rehmet
Zeitschrift fur Physik, 163, 2, 197 (1961)

Number 188

Continuously Operating Laser
British Communications & Electronics, 8, 4, 265, (April, 1961)

Number 190

Cavity Modes in an Optical Maser
W. G. Wagner and G. Birnbaum
Proceedings of the Institute of Radio Engineers, 49, 2, 625, (March 1961)

Number 198

Quantum Electronics
Editor. Charles H. Townes
Columbia University Press, New York, N. Y. (1960)

Number 199

Advances in Quantum Electronics
Editor. Jay R. Singer
Columbia University Press, New York, N. Y. (1961)

II. Solid State Materials - Ruby

Number 15

Masers
Weber, J. (University of Maryland)
Review of Modern Physics, Vol. 31, No. 3, p. 681 (July 1959)

This article is on microwave amplifiers. The Appendix has machine calculations of matrix elements and energy levels for ruby.

Number 33

Paramagnetic Resonance of Gd^{3+} in Al_2O_3
Geschwind, S., Remeika, J. P., (Bell Telephone Laboratories)
The Physical Review, Vol. 122, No. 4, p. 757 (May 1961)

The electron paramagnetic resonance spectrum of a small impurity of Gd^{3+} in Al_2O_3 has been examined at 24 kmc/sec. The substitution of Gd^{3+} for Al^{3+} whose ionic radius is half as large, would indicate that at impurity levels less than 0.02 percent the matching of ionic radii is not an all important criteria.

Number 43

The Effect of Temperature Upon the Absorption Spectrum of a Synthetic Ruby
N. S. Gibson
The Physical Review, Vol. 8, No. 1 p. 38-47 (1916)

The effect of temperature (-180° to 430°C) upon the absorption spectrum of a synthetic ruby is determined. Results show how transmission and absorption vary with λ at different temperatures. The wavelengths of the various lines and bands in the absorption spectrum have been determined.

Number 52

Absorption Spectra of Cr^{3+} in Al_2O_3
S. Sugano and Y. Tanabe
Journal Physical Society of Japan, 13, 8, 880-899 (1958)

This very detailed article consists of two parts. A detailed description of the Cr^{3+} excited states in the frame work of crystalline field theory is followed by a treatment taking into account the effects of trigonal fields and spin-orbit coupling (18 refs).

Number 54

On the Absorption Spectra of Rubies at Low Temperatures (to 1.7°K)
S. V. Grzhimailo et alia
Tom VI, Vyp. 2 Optika I Spektroskopiia
Fevral 1959
Vol VI, No. 2 Optics and Spectroscopy, p. 154 (February 1959)

Absorption spectra were determined at plane parallel sections of a ruby crystal (0.4 to 2.3 mm thick) in plane polarized light from a 10 cm crystal of Iceland Spar, allowing ordinary and extra ordinary absorption spectra to be taken simultaneously (8 refs).

Number 55

Absorption Spectra of Vanadium-Colored Corundium at Low Temperatures (to 1.7°K)
S. V. Grumm-Grzhimailo et alia
Tom VI, Vyp. 2 Optika i Spektroskopiia, Fevral 1959
Vol VI, No. 2 Optics and Spectroscopy, p. 152 (February 1959)

It is shown that practically the whole region of absorption consists of a series of broad bands. Only at 77°K were narrow absorption lines found in the blue region of the spectrum (λ = 4956Å, λ = 4757Å) (3 ref).

Number 56

Absorption Lines of Cr^{3+} in Ruby
W. Low; (Department of Physics, Hebrew University of Jerusalem)
Journal of Chemical Physics, Vol. 33, No. 4, p. 1162 (October 1960)

The line spectrum of Cr in ruby has been investigated. Lines were found at 14793, 14950, and 15178 cm^{-1}. These lines have been identified as belonging to the ^2F, triplet. Similarly a line at 21352 cm^{-1} has been assigned to the $^2F_2$ triplet (5 refs).

Number 65

Stimulated Optical Emission from Exchange Coupled Ions of Cr^{3+} Al_2O_3
Irwin Wieder and Lynn R. Sarles (Varian Associates)
Physical Review Letters Vol. 6, No. 3 (February 1, 1961)

This is a report of stimulated emission at wavelengths of 6943, 7010, and 7040 A from transitions in red ruby ($\sim$0.7 percent Cr^{3+} by weight) which arise from exchange coupling between neighboring Cr ions.

Number 84

Paramagnetic Resonance of Gd^{3+} in Al_2O_3
S. Geschwind and J. P. Remeika (Bell Telephone Laboratories)
The Physical Review, Vol. 122, No. 4, pp 757-761 (May 1, 1961)

The electron paramagnetic resonance spectrum of a small impurity of Gd^{3+} in Al_2O_3 has been examined at 24 kmc/sec. An important conclusion was drawn that matching of ionic radii is not an important criterion for incorporating an impurity ion into a lattice when concentrations of less than 0.02 percent are involved.

Number 93

Power Output Characteristics of a Ruby Laser
Malcolm L. Stitch (Hughes Aircraft Co.)
Journal of Applied Physics, Vol. 32, No. 10, 1994-1999 (October 1961)

The theoretical power output of a ruby laser is examined under certain idealized operating conditions, and it is found that there are two principal regions of operation. Efficiency of operation is examined under two limiting conditions.

Number 94

Optical and Microwave-Optical Experiments in Ruby
T. H. Maiman
Physical Review Letters, 4, 11, p. 564 (June 1, 1960)

Following 4 recent papers by Wieder, Varsanyi, Geschwind, and Brossel, the author reports new experiments concerning the fluorescent relaxation processes in ruby (0.05 percent weight Cr_2O_3) (4 refs).

Number 96

Self Absorption and Trapping of Sharp-Line Resonance Radiation in Ruby
F. Varsanyi, D. L. Wood, and A. L. Schawlow (Bell Telephone Laboratories)
Physical Review Letters Vol. 3, No. 12, p. 544 (December 15, 1959)

The details of the sharp line fluorescence of ruby (Cr^{3+} in Al_2O_3) were examined using high resolution optical spectroscopy. Radiative lifetimes and absorption coefficients are given.

Number 101

Optical and Microwave-Optical Experiments in Ruby
T. H. Maiman (Hughes Research Laboratories)
Physical Review Letters, Vol. 4, No. 11 (June 1, 1960)

Observations of ground state population changes in ruby due to optical excitation and the detection of optical absorption between two excited states in the crystal are reported.

Number 103

Optical and Microwave-Optical Experiments in Ruby
T. H. Maiman (Hughes Research Laboratories)
Physical Review Letters, Vol. 4, No. 11, p. 564-566 (June 1, 1960)

Experiments concerning the fluorescent relaxation processes in a ruby crystal when irradiated with 5600 Å radiation are reported.

A report of the first observations of ground-state population changes due to optical excitation and the detection of optical absorption between two excited states of 3600 Å radiation is also presented.

Number 105

Optically Efficient Ruby Laser Pump
P. A. Miles and H. E. Edgerton (Massachusetts Institute of Technology)
Journal of Applied Physics, Vol. 32, No. 4, 740-741 (April 1961)

Experimental observations of pumping energy required for optical maser operation as a result of various optical coupling arrangements between the input light and the crystal are reported.

Number 106

A Ruby Laser with an Elliptic Configuration
M. Clifton, C. F. Luck, C. G. Shaefer, H. Statz
Proceedings of the Institute of Radio Engineers, Vol. 49, No. 5, p. 960-61 (May 1961)

A description of the newly designed optical maser with an elliptical reflector, used to focus the pump energy onto the ruby rod, is reported. The device, weighing only nine pounds, including a transistorized power supply, is also shown schematically. An energy level diagram and an intensity curve are also available.

Number 107

Simultaneous Optical Maser Action in Two Ruby Satellite Lines
A. L. Schawlow and G. E. Devlin (Bell Telephone Laboratories)
Physical Review Letters, Vol. 6, No. 3, p. 96-98 (February 1, 1961)

Simultaneous oscillation at 7009 and 7041 Å in concentrated Ruby (0.5 percent Cr^{+3} in Al_2O_3) is reported as having been obtained. Consideration for using the strongest line for optical maser action is also discussed.

Number 108

Electronic Spectra of Exchange-Coupled Ion Pairs in Crystals
A. L. Schawlow, D. L. Wood, and A. M. Clogston (Bell Telephone Laboratories)
Physical Review Letters, Vol. 3, No. 6 (September 15, 1959)

The emission of sharp lines near 7000 Å in the fluorescence spectrum of ruby is attributed to strong exchange forces between neighboring Cr^{3+} ions. The intensity ratio of the 7010 Å line to the main line in ruby is shown as a function of chromium concentration.

Number 110

Theory of the Pulsation of Fluorescent Light from Ruby
R. W. Hellwarth (Hughes Research Laboratories)
Physical Review Letters, Vol. 6, No. 1 (January 1, 1961)

Equations are developed for induced fluorescence on ruby which predicts that as long as the pump power is above a certain threshold, part of the fluorescent power will occur in recurrent bursts or pulses. Quantitative estimates of the pulse repetition rate, the fraction of power in the pulses, and the nature of the output between pulses are derived in terms of the pump power and the ordinary properties of the crystal and end plates.

Number 115

Optical Detection of Paramagnetic Resonance in an Excited State of Cr^{+3} in Al_2O_3
S. Geschwind, R. J. Collins, and A. L. Schawlow (Bell Telephone Laboratories)
Physical Review Letters, Vol. 3, p. 545-548 (December 15, 1959)

Observations of paramagnetic resonance in an excited metastable state of Cr^{+3} in Al_2O_3 by a method of optical detection are reported. This method is based upon the selective reabsorption in the ground-state Zeeman levels of the fluorescent light from excited states in solids at low temperatures (1.6°K). Techniques are mentioned also.

Number 117

Thermal Tuning of Ruby Optical Maser
I. D. Abella and H. Z. Cummins (Columbia Radiological Laboratory)
Journal of Applied Physics, Vol. 32, No. 6, p. 1177 (June 1961)

Experiments performed pertaining to polarization and frequency stability (tunability) of the output of a pulsed ruby maser are reported. Curves representing the output frequency as a function of crystal temperature are also presented.

Number 119

Optical Detection of Paramagnetic Resonance Saturation in Ruby
I. Wieder (Westinghouse Research Laboratories)
Physical Review Letters, Vol. 3, No. 10 (November 15, 1959)

Experiments using optical pumping and microwave saturation to create disturbed population levels in ruby were conducted. Those involving microwave saturation showed a variation in transmitted light (R_2) through the ruby.

Number 120

Optical Detection of Paramagnetic Resonance in Crystals at Low Temperatures
J. Brossel, S. Geschwind, and A. L. Schawlow (Bell Telephone Laboratories)
Physical Review Letters, Vol. 3, p. 548-549 (December 15, 1959)

Techniques used for obtaining a population difference between the Zeeman substrates necessary for detection are discussed. Two cases are considered:

1) Fast thermalization - In Ruby, the Boltzman distribution is reached before atoms radiate.
2) Slow thermalization - Optical detection of magnetic resonance in the ground state by means of the change of paramagnetic to diamagnetic. Faraday effect and absorption of polarized light are also reported.

Number 167

Effect of Pressure on the Spectrum of Ruby
D. R. Stephens and H. G. Drickamer (University of Illinois)
Journal of Chemical Physics, 35, 2, 427-9 (August 1961)

The effect of pressure has been measured on the spectrum of ruby, both parallel and perpendicular to the C axis, to 120 k bar. From these data it is possible to calculate the change in crystal field strength Dq in interelectronic repulsion B and in trigonal field distortion (-3/2K). The crystal field increases with increasing pressure, while the B decreases, indicating increasing covalency. Graphs of ΔV, $\Delta 100q$, and B versus pressure are shown. The fractional change in Dq with pressure follows the R^{-5} law closely to 30 k bar.

Number 169

Hyperfine Spectrum of Chromium in Al_2O_3
R. W. Terhune and J. Lambe (Ford Motor Co., Dearborn, Michigan), and
C. Kikuchi and J. Baker (University of Michigan, Ann Arbor, Michigan)
Physical Review, 123, 4, 1265-8 (August 15, 1961)

Electron nuclear double-resonance techniques were used to observe the hyperfine spectrum of Cr^{53} in Al_2O_3. Through analysis of the spectrum at zero degrees a positive value of 48.5± 0.1 mc/sec was obtained for the hyperfine coupling constant and -0.85± 0.04 mc/sec for the quadrupole coupling constant. From this value of -0.03 barn was deduced for the quadrupole moment of Cr^{53}.

Number 173

Ultraviolet Absorption Spectra in Ruby
A. Linz Jr., and R. E. Newnham (Laboratory for Insulation Research, Massachusetts Institute for Technology, Cambridge, Massachusetts)
Physical Review, 123, 2, 500-1 (July 15, 1961)

The optical properties of highly doped rubies have been investigated. Al_2O_3 and Cr_2O_3 form a complete solid solution series; single crystals containing up to 5 mole percent chromia were grown by the Verneuil technique. The optical absorption of a group of ultraviolet crystal-field bands near 3400 Å were studied as a function of temperature, crystal orientation, and chemical composition. The intensity of these absorption bands varies with the square of the chromium concentration, perhaps indicating some strong chromium-pair interactions.

Number 180

Effect of Configuration Mixing and Covalency on the Energy Spectrum of Ruby
S. Sugano and M. Peter (Bell Telephone Laboratories, Murray Hill, New Jersey)
Physical Review, 122, 2, 381-6 (April 15, 1961)

To improve the analysis of the microwave and optical spectrum of ruby, a calculation has been performed in the strong cubic field scheme, taking into account configuration mixing of the higher excited $t_2{}^2e$ states into the $t_2{}^3$ states. In calculation, covalency of the t_2 and e electrons is is introduced besides the spin-orbit interaction, trigonal field, and Zeeman energy. The results show that configuration mixing and covalency play an important role in giving zero-field splittings and g values of the $t_2{}^3$ states.

Number 184

Cross Relaxation and Concentration Effects in Ruby
Roy W. Roberts (Melabs, Palo Alto, California)
Physical Review, 121, 4, 997-1000 (February 15, 1961)

It is shown that cross relaxation can improve maser performance even in the absence of impurity doping. There are certain regions of low concentrations in which individual cross relaxation processes can be observed. Energy level diagrams for chromium doped sapphire for certain values of field strength applied at certain angles are given and indicate the three-, four-, and five-spin cross relaxation processes. Diagrams of signal transmission through a traveling wave maser versus time are given.

Number 195

Optical Properties of Sapphire in the Far Infrared
Ernest V. Loewenstein (The John Hopkins University, Baltimore, Maryland)
Journal of the Optical Society of American 51, 1, 108(61)

Investigations of the optical properties of artificial sapphire in the far infrared have been undertaken utilizing the channel spectrum. The instrument used is a large interferometer designed for application in the far infrared. Sapphire is found to be highly transparent from 10 to 40 cm^{-1}, with transmission dropping to zero near 90 cm^{-1}. The index of refraction was available directly from the interferogram since it remains substantially constant in the far infrared.

III. Solid State Materials - Fluorides

Number 7

Stimulated IR Emission from Trivalent Uranium
Sorokin, P. P., Stevenson, M. J. (IBM)
Physical Review Letters, Vol. 5, No. 12, p. 557 (December 15, 1960)

A description of the characteristics of stimulated emission from trivalent uranium ions substituted for divalent calcium ions in calcium fluoride is provided.

Number 24

The Luminescence of Trivalent Uranium
L. N. Galkin and P. P. Feofilov
Soviet Physics, Doklady Vol. 2, No. 3 (May-June 1957)

Descriptive article on the investigation of fluorescence in the infrared region (2.0-2.5μ) of Ur:CaF_2, Ur:SrF_2, Ur:BaF_2. This article was presented before the use of stimulated emission in the optical or infrared region. The absorption spectrum of the above is also discussed.

Number 26

Optical Pumping in Crystals
Theissing, H. H.; Caplan, P. J.; Dieter, F. A.; Rabbiuer, N.
United States Signal Corps, Research and Development Laboratories, Fort Monmouth, New Jersey
Physical Review Letters, 3, 460-461 (November 1959)

A review of the CaF_2 (or $SrCl_2$):Eu^{2+} laser is provided. Calculations of both the ground and excited state and transition probabilities are also presented. A list of pumping factors is included.

Number 34

Fluorescence and Optical Maser Effects in CaF_2:Sm^{++}
W. Kaiser, C. G. B. Garrett, and D. L. Wood (Bell Telephone Laboratories)
Physical Review, Vol. 123, No. 3, 766-776 (August 1, 1961)

Measurements are reported of absorption, emission, and activation spectra in CaF_2:Sm^{++}, and also fluorescence lifetime. Observations of optical maser effects were made at liquid hydrogen and liquid helium temperatures.

Number 37

Optical Pumping of Eu in CaF_2 and $SrCl_2$
Series, G. W. and Taylor, M. G.
Journal De La Physique Et Le Radium 19, p. 901 (Nc ember 1958)

Paper given at the Colloque International e Sur la Résonance magnétique, July 1958, Paris. Gives a theoretical calculation of relaxation times and pumping rates. Eu^{++} is given as an example.

Number 45

Solid State Optical Maser Using Divalent Samarium in Calcium Fluoride
P. P. Sorokin, M. G. Stevenson
IBM Journal 5, 1, p. 56 (January 1961)

Number 46

Growth of Single-Crystal Calcium Fluoride with Rare-Earth Impurities
H. Guggenheim (Bell Telephone Laboratories, Inc., Murray Hill, New Jersey)
Journal of Applied Physics 32, 7, (1337-1338) (July 1961)

Number 53

On Absorption and Luminescence Spectra of Ce^{+++} ions
P. P. Feofilov
Tom VI Vyp2 Optika i Spektroskopiia (Fevral 1959)
Vol VI, No. 2 Optics and Spectroscopy, p. 150 (February 1959)

Number 60

Two-Photon Excitation in CaF_2: Eu^{2+}
W. Kaiser and C. G. B. Garrett (Bell Telephone Laboratories)
Physical Review Letters, Vol. 7, No. 6 (September 15, 1961)

Experimental investigation of the generation of blue fluorescent light around $\lambda = 4250$ Å from a CaF_2: Eu^{2+} crystal illuminated with the output of an optical maser ($\lambda = 6943$ Å) is presented. The result is attributed to a two photon process.

Number 66

Stimulated Infrared Emission from Trivalent Uranium
P. P. Sorokin and M. J. Stevenson (IBM)
Physical Review Letters, Vol. 5, No. 12, p. 557 (December 15, 1960)

The operation of a maser using stimulated emission from trivalent uranium ions substituted for divalent calcium ions in CaF_2 is described. Experimental results are

provided. The low pumping power required indicates this arrangement might be suitable for a cw infrared laser.

Number 156

Optical Maser Characteristics of Nd^{+3} in CaF_2
Leo F. Johnson (Bell Telephone Laboratories)
Journal of Applied Physics, Vol. 33, No. 2, p. 756, (February 1962)

IV. Solid State Materials - Tungstates and Others

Number 94

Paramagnetic Resonance Study of Irradiated Single Crystals of Calcium Tungstate
Henry Zeldes and Ralph Livingston (Oak Ridge National Laboratory, Oak Ridge, Tennessee)
Journal of Chemical Physics, 34, 1, 247-252 (January 1961)

Gamma irradiation of calcium tungstate at 77°K produces two paramagnetic species in high yield. Principal axis directions and g tensors have been measured and indicate one species contains a surplus electron and the other is electron deficient. One group of lines was observed at magnetic field strengths near that corresponding to the free electron g value and the other was at much higher fields. Photographs of low field lines are shown for various angles between the field and the C axis. Tables of principal axis directions and values of g are given for low and high field lines.

Number 148

Infrared Fluorescence and Stimulated Emission of Nd^{+3} in $CaWO_4$
L. F. Johnson and K. Nassau
Proceedings of the Institute of Radio Engineers, Vol. 49, No. 11, p. 1704, (November 1961)

Observations of infrared fluorescence and stimulated emission at room temperature or at 77°K in a $CaWO_4$ median doped with trivalent neodymium ions are reported. Infrared fluorescence spectrum for various pumping intensities above threshold are also shown.

Number 157

Optical Maser Characteristics of Nd^{+3} in $SrMoO_4$
L. F. Johnson and R. R. Soden (Bell Telephone Laboratories)
Journal of Applied Physics, Vol. 33, No. 2, p. 757 (February 1962)

A description of the optical maser characteristics using Nd^{+3} doped $SrMoO_4$ is given. Various oscilloscope traces of lamp intensity versus time and fluorescence versus time are also given.

Number 165

Optical Absorption Spectra of Nickel-Doped Oxide Systems. I
R. Pappalardo, D. L. Wood, and R. C. Linares, Jr. (Bell Telephone Laboratories Inc., Murray Hill, New Jersey)
Journal of Chemical Physics, 35, 4, 1460-78, (October 1961)

The optical absorption was studied at room temperatures, at 78°, and 4.2°K in the 2.6μ to 0.2μ region in the single crystals of MgO, ZnO, $MgAl_2O_4$, and yttrium-gallium garnet doped with nickel. The absorptions found were correlated to electronic transitions within the 3d-shell using the formalism of the crystal field theory. The value for the Dq and B parameters were derived for MgO: Ni and for ZnO: Ni where Ni is tetrahedrally coordinated. Interesting fine structure was found in the absorption spectra of MgO: Ni and its implications are discussed.

Number 166

Studies of the Optical and Infrared Absorption Spectra of Rutile Single Crystals
Bernard H. Soffer, Laboratory for Insulation Research, (Massachusetts Institute of Technology, Cambridge, Mass.)
Journal of Chemical Physics, 35, 3, 940-5 (September 1961)

The optical absorption of single crystals of synthetic rutile was investigated in the spectral range 1200 to 25,000 cm^{-1} from room temperature to 1000°C. The electronic absorption exhibits dichroic behavior. The edge moves toward lower energies as temperature is increased with the shift depending on the absorption coefficient. The broad band in the region of 6850 cm^{-1} which occurs in reduced rutile does not appear in fully oxidized rutile, even at high temperatures.

V. Maser Optics

Number 86

Proposed Fiber Cavities for Optical Masers
E. Snitzer (American Optical Company)
Journal of Applied Physics, Vol. 32, No. 1, 36-39, (January 1961)

The use of dielectric waveguides in the form of small fibers as the mode selector in optical masers is considered. The principal advantages of the fiber are mode selection and stronger mode coupling. The major disadvantage is the difficulty of pumping into the small volume of the fiber.

Number 88

A New Method of Transporting Optical Images Without Aberrations
A. C. S. van Heel (Labor voor Technische, Delft, Holland)
Nature 173 p. 39 (1954)

The first fiber optics used in Holland are described. The development starting in 1950 with glass fibers and leading to plastic fibers is reviewed. (Good basic description)

Number 89

Optical Waveguide Modes in Small Glass Fibers
E. Snitzer (American Optical Company), and J. W. Hickes (Mosaic Fiber Inc.)
Journal of the Optical Society of America 49, 11, p. 1128 (1959)

The article gives a detailed description of the theory of optical waveguides which is followed by a description of the experimental results with glass fibers.

Number 113

Cylindrical Dielectric Waveguide Modes
E. Snitzer (American Optical Company)
Journal of the Optical Society of America, Vol. 51, No. 5, 491-498 (May 1961)

The propagation of cylindrical dielectric waveguide modes near cutoff and far from cutoff are considered. The relative amounts of E_z and H_z, and the transverse components of the field are determined for both sets of hybrid modes.

Number 114

Observed Dielectric Waveguide Modes in the Visible Spectrum
E. Snitzer and H. Osterberg (American Optical Company)
Journal of the Optical Society of America, Vol. 51, No. 5, 499-505 (May 1961)

Direct images and radiation patterns of the first few lowest order dielectric waveguide modes were observed in the visible region of the spectrum. Core diameters were 0.1 to 5.5μ. Photographs of the modes are shown.

VI. Properties (Coherence and Others)

Number 28

Report on Coherence Properties of Electromagnetic Radiation, (held at the University of Rochester; June 27 - June 29, 1960)
Hopkins, R. E.
AD No. 256057 (250 pages)

This is a very thorough investigation of the meaning and aspects of coherence. Includes descriptive papers of work performed by some of the recognized leaders in maser-laser field. Extremely informative and applicable to researchers who are engaged in the field.

Number 59

Some Properties of Coherent Light
L. Mandel and E. Wolf (Institute of Optics, University of Rochester)
Journal of the Optical Society of America, Vol. 51, No. 8 (August 1961)

A study of some general properties of coherent light is given. Coherence is defined and theorems relating to correlation functions and the spectral density functions of coherent light are derived. The results are used to establish the Huygens-Fresnel principle for a coherent optical field.

Number 64

Incoherent Source with an Arbitrarily Narrow Power Spectrum
T. J. Skinner (Air Force Cambridge Research Labs.)
Journal of the Optical Society of America, Vol. 51, No. 8, (August 1961)
(Letter)

Coherent light is defined utilizing the mutual coherence function. A mathematical model of an incoherent light source with an arbitrarily narrow power spectrum is constructed. The results indicate that coherence cannot be equated to a narrow-power spectrum.

Number 67

Photon Degeneracy in Light from Optical Maser and Others Sources
L. Mandel (University of Rochester, Rochester, New York)
Journal of the Optical Society of America, Vol. 51, No. 7, p. 797-798
(July 1961)

The article describes the degeneracy parameter (δ). δ is the average number of photons in the light beam which are to be found in the same quantum state: $3x10^{-4}$ for incandescent source; 10^{-3} some gas discharge sources; and $5x10^{7}$ for solid state optical maser.

Number 104

Spacial Coherence in the Output of an Optical Maser
D. F. Nelson and R. J. Collins (Bell Telephone Laboratories)
Journal of Applied Physics, Vol. 32, No. 4, p. 739 (April 1961)

A study pertaining to the coherence of the output of a pulsed ruby optical maser is reported. The interference fringes produced by the light emerging from a double slit placed in contact with the ruby rod is discussed.

Number 111

Resonant Modes in an Optical Maser
A. G. Fox and T. Li (Bell Telephone Laboratories)
Proceedings of the Institute of Radio Engineers (Correspondence), p. 1904-1905 (November 1960)

A computer was programmed to investigate bouncing a wave back and forth repeatedly between plane parallel mirrors of zero reflection loss. It was observed that the diffraction loss not only caused the wave to grow weaker, but the amplitude at the edges dropped to a small fraction of the center value.

Number 180

Note on Coherence Vs. Narrowbandedness in Regenerative Oscillators, Masers, Lasers, etc.
M. J. E. Golay
Proceedings of the Institute of Radio Engineers, 49, 5, I, 958 (May 1961)

VII. Related Basic Research

Number 39

Absorption and Fluorescence Spectra of Trivalent Samarium, Europium, and Ytterbium
F. D. S. Butement
Transactions of the Farady Society, Vol. XLIV, p. 617-626 (1948)

The absorption and fluorescence of the trivalent rare earths have been studied. ($SmCl_3$, $EuCl_3$, and $YbCl_3$ in water; $SmCl_3$ in NaCl; $SmCl_3$ in $SrCl_2$; $SmCl_3$ in $BaCl_2$; $EuCl_3$ in $SrCl_2$; $EuCl_3$ in $BaCl_2$; $YbCl_3$ in $SrCl_2$; $YbCl_3$ in $BaCl_2$)

Number 41

Electron Spin Relaxation Times in Gadolinium Ethyl Sulfate
G. Feher and H. E. D. Scovil (Bell Telephone Laboratories)
Physical Review, Vol. 105, p. 760-763 (1957)

The preliminary results of an investigation of the electron spin relaxation times in dilute gadolinium ethyl sulfate with cerium as an additional impurity are reported. The successful operation of a maser using this material is also reported.

Number 47

Die Temperaturabhangigkeit der Ultrarotabsorption von Kristallen
Matossi, F. and Brix, H.
Zeitschrift fur Physik 92, p. 303 (1934)

The transmission of Getz between 2 and 5μ in the temperature region from 105 to 573°K is given. The main absorption is found to be at 13.8μ.

Number 57

Axial Crystal Fields in the Ionic Model
T. S. Piper and R. L. Carlin (University of Illinois)
Journal of Chemical Physics, Vol. 33, No. 4 (October 1960)

Expressions for the axial components of crystal fields of tetragonal, trigonal, and cylindrical symmetry are developed in terms of the parameters Ds and Dt. These parameters are calculated in the ionic model using Hartree - Fock 3d radial wave functions. The calculated parameters are compared to experimental values obtained from the spectra of V(III) in Al_2O_3 and Co(II) in CoO. Tentative assignments of the bands in the spectrum of $(C_5H_5)_2Ni$ are made (17 refs).

Number 63

Emission Spectra of the Doubly and Triply Ionized Rare Earths
C. H. Dieke, H. M. Crosswhite, and B. Dunn (Johns Hopkins University Baltimore, Maryland)
Journal of the Optical Society of America, Vol. 51, No. 8, 820-827 (August 1961)

The general features of the spectra of the doubly and triply ionized rare earths are discussed. Controlled excitation was utilized to provide maximum intensity on spectral photographs.

Number 83

EPR and Spin Lattice Relaxation of Co^{2+} in Al_2O_3
G. M. Zverev, A. M. Prokhorov
J. E. T. P. 12, 1, 41-43 (1961) (in English)

The electron paramagnetic resonance of Co^{2+} in corundum has been observed and the Spin Hamiltonian Constants for the two nonequivalent ion systems have been measured. An anomalously large relaxation time was found. Further experiments were announced.

Number 91

Induced and Spontaneous Emission in a Coherent Field
I. R. Senitzki (U. S. Army Signal Research and Development Laboratory)
The Physical Review 119, 1807 (1960)

This article is divided in three parts and gives an extended treatment of the theory of the interaction between the electromagnetic field in a cavity resonator and a number of two-level molecules.

Number 95

Optical Detection of Paramagnetic Resonance in Crystals at Low Temperatures
J. Brossel, S. Geschwind, and A. L. Schawlow (Bell Telephone Laboratories)
Physical Review Letters, Vol. 3, No. 12 (December 15, 1959)

A general description of methods of detecting magnetic resonance in the fluorescent state of crystals is provided. The use of selective reabsorption techniques and also of the more conventional double resonance techniques are described.

Number 125

Photoelectric Mixing as a Spectroscopic Tool
A. T. Forrester (Electro-Optical Systems Inc.)
Journal of the Optical Society of America, Vol. 51, No. 3, pp. 253-259 (March 1961)

Photoelectric mixing when combined with the use of optical masers is considered for use in optical measurements. The receivers types considered are termed low-level and super heterodyne. In these receivers the detector or mixer is a photocell or other photoelectric device.

Number 130

Measurements of Radiative Lifetimes
W. R. Bennett, Jr., A. Javan, and E. A. Ballik (Bell Telephone Laboratories)
Bulletin of the American Physical Society 11, 5, 496 (1960)

Paper presented at the 1960 Physical Society Winter Meeting at University of California, Berkeley, California. Description of a newly developed apparatus for lifetime measurements.

Number 145

Optical Absorption Lines of Hydrated Manganous Salts at Low Temperatures
R. Pappalardo (H. H. Wills Physics Laboratory)
Philosophical Magazine, Vol. 2, p. 1397, (1957)

The absorption spectra of four manganous hydrated salts (sulphate, chloride, fluosilicate, and ammonium sulphate) have been investigated at 78° and 20°K in the 15,000 cm^{-1} to 30,000 cm^{-1} range. Several groups of lines are found, some of them showing subsplitting of the order of 10 cm^{-1}. The results are satisfactorily interpreted by means of the liquid field theory: a qualitative discussion of refinements of the cubic field scheme in relation to the observed spectra is also given.

Number 147

The absorption Spectra of Manganese Fluoride, Zinc Fluoride, and Manganese-Activated Zinc Fluoride
W. W. Parkinson, Fred E. Williams (University of North Carolina)
Journal of Chemical Physics, Vol. 18, No. 4, p. 534 (April 1950)

Optical absorption spectra of luminescent solids necessary for the determination of the precise transitions involved in luminescence are discussed. The experimental techniques used for sample preparation, analyses, and precise measurements are also reported. A schematic of the absorption apparatus and several plots of the absorption data are presented also.

Number 160

Crystal Vacancy Evidence from Electron Spin Resonance
John E. Wertz and Peter Auzins (School of Chemistry, University of Minnesota, Minneapolis, Minnesota)
Physical Review, 106, 3, 484-8 (May 1, 1957)

Three distinct patterns have been observed in the electron spin resonance (ESR) of chromium (+3) ions in single crystals of MgO. The Cr (+3) spectrum depends upon whether compensation for the extra charge occurs in the immediate vicinity, and if so, upon the position of the compensating charge. The ESR spectra of Cr (+3) are shown for two patterns.

Number 171

Spin-Lattice Relaxation in Imperfect Cubic Crystals and in Non-Cubic Crystals
Professor E. R. Andrew and D. P. Tunstall
Proceedings of the Physical Society of London 28, (I), P499, pl, (July 1, 1961)

Number 174

Cesium Transition Probabilities for Optical Pumping
W. Bruce Hawkins (Department of Physics, Oberlin College, Oberlin, Ohio)
The Physical Review, 123, 2, 544-7 (July 15, 1961)

Optical transition probabilities are presented between the several magnetic sublevels of the C_s133 ground state via the first excited state, given separately for the two fine-structure components. Graphs of the populations of representative states are presented as a function of the time the atoms are illuminated, and a table is given of the populations of atoms absorbing integral numbers of photons from both D lines simultaneously both polarized and unpolarized.

Number 178

The State of the Neodymium Ion as Derived from the Absorption and Fluorescence Spectra of $NdCl_3$ and Their Zeeman Effects
E. H. Carlson and G. H. Dieke (The John Hopkins University, Baltimore, Maryland)
Journal of Chemical Physics, 34, 5, (1602-9) (May 1961)

The absorption and Fluorescence spectra of Nd^{3+} in $NdCl_3$ diluted by $LaCl_3$ were examined with their Zeeman effects at 4.2° and 77°K. The empirical energy-level diagram is shown and is complete up to 28,000 cm^{-1} except for the locations of the 2K term. Crystal stark splittings, magnetic properties, and intensities are compared to calculated values obtained from an intermediate coupling calculation of the $4f^3$ configuration.

Number 182

Luminescence During Annealing and Phase Change in Crystals
Nove M. Johnson and Farrington Daniels (Departmont of Chemistry, University of Wisconsin, Madison, Wisconsin)
Journal of Chemical Physics, 34, 4, 1434-9 (April 1961)

Thermoluminescence is defined as the thermal release of trapped electrons with accompanying optical transition. Although this presupposes an exposure to ionizing radiation, these other processes such as mechanical stress and chemical reaction can also serve to excite the electrons. Measurements of annealing and polymorphic changes made with x-ray diffraction prove this fact. Studies of geological specimens by thermoluminescence must account for both types of light generations.

Number 189

Measurement of Anomalous Absorption Coefficients of Electrons for MGO Crystals
Kazutake Kohra and Hiroshi Watanabe
Journal of the Physical Society of Japan, 16, 3, 580, (March 1961)

VIII. Gaseous Organic, Semi-conducting Masers

Number 16

Investigation of Population Inversion in He
Condell, W. J., Van Guntur, O, Bennett H. S. (Division of Physical Sciences, University of Maryland, College Park, Maryland)
Journal of the Optical Society of America, Vol. 50, No. 2, p. 184 (Feb 1960)

Number 22

Realization of a Medium with a Negative Absorption Coefficient
V. K. Ablekov, M. S. Peskin, and I. L. Fabelenskii
Journal of Experimental and Theoretical Physics 39, p. 892 (Oct 1960)

Using a gas discharge in a mixture of mercury and zinc, (6° to 15°C) (8-15 amp), a negative absorption coefficient for the zinc line 6362Å was observed. The energy exchange is attributed to resonance collisions of the second kind between the excited atoms of mercury and unexcited atoms of zinc. (Excitation energy difference is only 133 cm^{-1} [$\approx 2.64 \times 10^{-14}$ erg] between the mercury and zinc levels.)

Number 62

Population Inversion and Continuous Optical Maser Oscillation in a Gas Discharge Containing a He-Ne Mixture
A. Javan, W. R. Bennett, Jr., and D. R. Herriott (Bell Telephone Laboratories)
Physical Review Letters, Vol. 6, No. 3 (Feb 1, 1961)

A gaseous discharge consisting of a He-Ne mixture has led to the successful operation of a continuous wave optical maser. This letter provides a summary of the results of experimental determinations of several physical properties.

Number 81

Possibility of Production of Negative Temperature in Gas Discharges
A. Javan (Bell Telephone Laboratories, Murray Hill, New Jersey)
Physical Review Letters, 3, 2, 87-88 (July 15, 1958)

To obtain maser action in the optical region a method of obtaining negative temperature by optical pumping has been proposed. A new method has been devised to obtain negative temperatures; that is by the excitation of atomic levels by electrons in discharge. The limitations and the types of systems proposed are discussed. The necessity of high pressures and moderate electron densities is pointed out.

Number 176

Luminescence of Chromium (III) Complexes
Leslie S. Forster and Keith DeArmond (Department of Chemistry, University of Arizona, Tucson, Arizona)
Journal of Chemical Physics, 34, 6, 2193-4 (June 1961)

The emission bands of Cr(III) were studied in the chelates $Cr(aca)_3$ and $Cr(hq)_3$. The observations were made at -183°C. A diagram of the absorption and emission spectra of $Cr(aca)_3$ is shown. The crystal field absorption band in $Cr(hq)_3$ is not as well resolved as in $Cr(aca)_3$ and the emission is more asymmetric with tailing on the low-frequency side. The emission can be excited with 3660, 4358, and 5640Å radiation and is essentially localized in the Cr(III) ion.

Number 196

Coherent Light Amplification in Optically Pumped Cs Vapor
S. Jacobs, G. Gould, and P. Rabinowitz, Technical Research Group Inc., Syosset, New York)
Physical Review Letters 7, 11, 415-17 (Dec 1, 1961)

An excess population density in the upper of two states connected by an optical transition makes laser action possible. This has been demonstrated in a system using cesium vapor excited by selective optical pumping laser action which was found to be possible at $\lambda = 7.2\,\mu$ and $3.2\,\mu$. The derivation of the amplification coefficient is shown. A complete description of the equipment used, the method of operation, and the different checks made in the procedure are given. The pumping is done by helium 3888Å radiation.

Number 197

Stimulated Light Emission by Optical Pumping and by Energy Transfer in Organic Molecules
D. J. Morantz, B. G. White and A. J. C. Wright (Chemical Department, Woolwich Polytechnic, London, England)
Physical Review Letters, 8, 1, 23-5 (Jan 1, 1962)

The phenomenon of stimulated emission in organic systems depends on the spin-forbidden triplet - singlet transition which is available particularly in organic systems. The system used comprised an aromatic molecular species in a rigid glass matrix at 77°K between parallel reflecting plates and was pumped by an intense flash of light. The range of molecules available will yield optical frequencies in the visible, ultraviolet, and infrared regions. Control of these frequencies can be made possible by small changes in the molecular structure.

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24. Journal De La Physique Et Le Radium (J. Phys. Radium)

25. L'Onde Eléctrique

Germany

26. Zeitschrift fur Physik

27. Optik

Aeronautical Systems Division, Dir/Materials and Processes, Physics Lab, Wright-Patterson AFB, Ohio.
Rpt. No. ASD-TDR-62-1026. ANNOTATED BIBLIOGRAPHY ON SOLID STATE OPTICAL AND INFRARED MASER MATERIALS. Final report, Jan.63, 33 pp., incl 110 refs.

Unclassified Report

This report contains abstracts of approximately 110 articles from 25 different scientific journals. It covers theory and survey; solid state maser materials; maser optics; properties (coherence and others); related basic research; and organic, semiconducting, and gas masers. The survey

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1. Solid state materials
2. Maser materials, annotated bibliography
3. Optical maser materials

I. AFSC Project 7371, Task 737101
II. Dieter Feldmann
III. Aval fr OTS
IV. In ASTIA collection

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